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Geometric characterization of Point Bar Deposits in the lower River Niger, Niger Delta.

Akana, S. Tombra[1] and Adeigbe, O.C[2]

Abstract

Remote sensing and GIS based results from the geometric characterization of point bar deposits in the Lower River Niger are presented in this work. In this study the geometry of 75- point bar deposits from Landsat images of 1985 and 2015 were documented and compared to determine the relationship that exist between geometric dimensions and the amount of change that has occurred on them. Point bars in 2015 are observed to be greater in length, width and area than those in 1985. The R^2 values indicate that no relationship exists between point bar length and width. However, a significant relationship is observed to exist between both length and area and width and area of the point bars within the study area. Thus, the utilization of width to predict the length and vice versa of point bars is unreliable. Information from this study provides useful information on specific shape and size ranges that can be utilized for the efficient characterization and development of hydrocarbon reservoirs.

Keywords: Lower River Niger, Remote sensing, GIS, Landsat, Point bar geometry.

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[1]Department of Geology, Pan African University Life and Earth Science Institute, University of Ibadan, Ibadan, Nigeria.
[2]Department of Geology, University of Ibadan, Ibadan, Nigeria

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1. Introduction

With fossil fuel in high demand worldwide, the focus of most oil producing countries and exploration companies is on identifying new reserves and fully optimizing old ones. The modern Niger Delta is evolving daily, impacted by the increasing activity within, both naturally and anthropogenically. Therefore, an understanding of the characteristics of the modern surface reserves would greatly improve exploration programs, reduce exploration and production costs and manage downtime in industry. Fluvial channel bar deposits especially point bars are known to be one of the best reservoirs within the Niger Delta because of their high sand ratio and thickness [1]. Thus, it is necessary to understand the external geometry of such an important landform which would lead to the effective characterization and development of similar hydrocarbon reservoirs [2].

Meandering rivers are known to deposit sand and mud within well-defined meander belts [3]. Macro landforms found in meander belts include point bars, crevasse splays, and mud-rich channel plugs within a background of floodplain muds [4]. This paper focuses on the Point bar macro landform. Although on the surface point bars are considered macro landforms, after they have undergone burial and diagenetic processes they reduce somewhat in size and therefore can be missed on seismic data due to resolution. Exploration wells which can address resolution problems are usually expensive to drill and spaced far apart and thus can also miss these point bars. Remote sensing which is a low-cost technique is suitable for studying modern fluvial channels and their landforms which in turn provide valuable information on the geometry of point bar deposits. The findings of such study can be utilized in ancient fluvial channel deposits as an input in characterization and development of hydrocarbon bearing reservoirs.

Very few literatures are available where the spatial geometry of point bars are considered [5]; [6]. However, through the study and understanding of the geometry of outcropped fluvial deposits [7] suggests exploration and exploitation potentials of hydrocarbon reservoirs can be improved. [4] studied the geometry surface landforms in the Mississippi river with the use of remote sensing techniques and established that a correlative relationship exists between length and width channel bars. He also suggests that geometric landform surface studies provide information which can aid cost efficient exploration and characterization of ancient fluvial hydrocarbon reservoirs.

2. Study Area

The Niger Delta Basin is situated in the Gulf of Guinea in equatorial West Africa, between latitudes 3°N and 6°N and longitudes 5°E and 8°E [8]. It is bound on the northwest by a subsurface continuation of the West African shield, the Benin Flank. The eastern edge of the basin coincides with the Calabar Flank to the south of the Oban Masif [9] on the south bound by the Atlantic Ocean (Figure 1). The proto delta developed in the northern part of the basin during the Campanian transgression and ended with the Paleocene transgression. Formation of the modern delta began during the Eocene, the three major depositional environments typical of most deltaic environments are the marine, transitional and continental represented in the Niger Delta basin by the Akata, Agbada and Benin Formations respectively. The delta has been fed by the Niger, Benue and Cross Rivers, which between them drain more than 106 km^2 of continental lowland savannah, The Niger-Benue river system alone brings a sediment load of about 0.02km^3/yr. which is deposited mainly on top the delta [10].

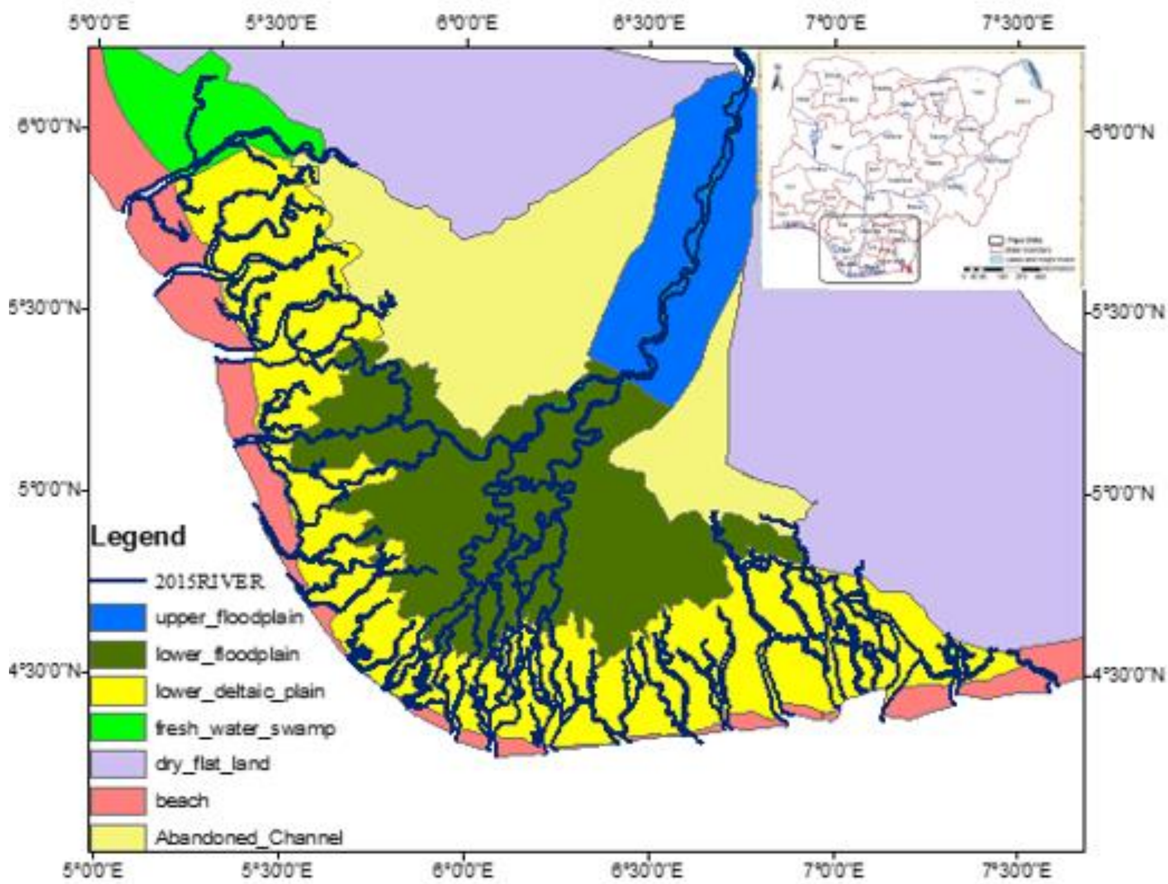

Figure 1: Geologic map of Niger Delta; study location and major sedimentary environments as defined by the fluvial, tidal and wave-related processes.

3. Data and Methodology

Satellite images of 1985 and 2015 (Landsat TM—resolution 30m) were used for assessing the geometric changes in channel bar (point bar) deposits over a 30-year period. All datasets were geometrically corrected and resampled to bring to the same scale [11]. Processing and interpretation of satellite imagery to delineate changes in point bar landforms and analysis of the dataset was achieved using ESRI ArcGIS 10.3 and ArcView 3.5 computer software. The procedures were tailored towards extracting quantitative parameters from the identified point bars using geoprocessing operations. The parameters estimated from the point bars include length, width and area. The length of the point bar is determined as the distance between the two terminal points along a bar. The width of a point bar is defined as the maximum length between the two end-to-endpoints across a bar. Length, width and area of the point bars have been measured within the Arc GIS software.

4. Results and Discussion

Channel- belt deposits formed in bends of meandering rivers tend to provide a good proxy estimate of paleo-channel depth (e.g., [12]; [13]). Therefore, channel depth can be estimated by measuring a completely preserved channel-bar-deposit [14]; [15]; [16]; [17]. There are 38-point bars mapped in the Niger Delta in 1985 and 37 in 2015. They are associated with the fluvial channels within the upper delta plain covering the upper and lower floodplains of the Niger Delta. The length of the point bars mapped varies between 476m and 9,305m in 1985 and 300m to 8,604m in 2015 whereas their width varied from 116m to 4896m in 1985 and 101m to 6490m in 2015 (Table 1). Area varied from 33,171m² to 22,499,271m² in 1985 and 53,286m² to 6,103,804m² in 2015. There is an average of 0.6% rate of change in the length of the point bars within the study period and a 2.6% of positive change affecting their width. An average of 8.6% rate of positive change affected the area of the point bars over the period of study (30 years) which lends to the high rates of erosion within the river Niger channel. The mode length of point bars increased from 1-4km in 1985 to 2.5-4.7km in 2015 whereas the width increased from 0.1km-1km in 1985 to 0.1km-1.6km in 2015. The mode area was also observed to increase from 0.1km-5km in 1985 to 0.1km-6.5km in 2015. This invariably implies that although deposition on the point bars were observed, erosion was prevalent over the study period. The overall geometry of point bars is not only influenced by sediment erosion and deposition along the channel bank but also depends on the river hydrodynamics. Low energy rivers with high braiding can also affect the formation and geometry of the point bars; as areas with high braiding index has less and or smaller sized point bars. On the other hand, braiding can trigger accumulation of the sediment at the banks which can initiate point bar formation [18]. However, most point bars evaluated in this study were associated with channel portions with little or no braiding and lower energy levels. The length, width and area, associated with the point bar are plotted to validate the dependence of these parameters to one another (Table 2).

Studies of point bars and related fluvial bodies by [19]; [20]; [21]; [22]; [23] have shown that relationships exist between parameters such as thickness, length and width, volume, river sinuosity and bend tightness. The plots of point bar length against area and the point bar width against area show a significant relationship in this study. This relationship can be used to determine missing geometric parameters in the subsurface during the exploration phase of a project. However, no significant relationship is observed to exist between point bar width and point bar length within the study period (Table 2). Hence the extrapolation of point bar width from bar length cannot be relied upon during the modelling of subsurface point bar reservoirs.

Table 1: Variation in geometric dimensions (length, width and area) of point bars (PB) within the Niger Delta between year 1985 and year 2015.

PB S/N	LENGTH (M)			WIDTH (M)			AREA (M^2)		
	YR 1985	YR 2015	% RC	YR 1985	YR 2015	% RC	YR 1985	YR 2015	% RC
1	3655	2857	-0.7	1231	1613	1.0	2873570	2262264	-0.7
2	8154	2042	-2.5	2060	805	-2.0	8872040	907228	-3.0
3	3874	2558	-1.1	643	860	1.1	1877913	1371097	-0.9
4	3218	3755	0.6	881	1277	1.5	1692639	2185746	1.0
5	3653	5199	1.4	1302	2471	3.0	2834949	10749460	9.3
6	3068	3243	0.2	1431	2093	1.5	2951935	4339841	1.6
7	2486	5140	3.6	679	2846	10.6	1368884	10630383	22.6
8	6098	3147	-1.6	2862	2216	-0.8	8952148	3092528	-2.2
9	5008	6933	1.3	2149	2743	0.9	7614191	10811505	1.4
10	5668	1950	-2.2	3228	287	-3.0	11283454	394892	-3.2
11	6434	7981	0.8	729	3406	12.2	2744708	16899259	17.2
12	5831	7091	0.7	1687	5255	7.0	7158460	21819150	6.8
13	1997	6566	7.6	795	4048	13.6	915618	15664665	53.7
14	7481	8604	0.5	4659	3216	-1.0	21499273	15647302	-0.9
15	7694	6485	-0.5	4896	6490	1.1	5582275	19598271	8.4
16	6175	3445	-1.5	3384	3437	0.1	1493120	11508165	22.4
17	9305	5543	-1.3	2142	3181	1.6	9938875	11212784	0.4
18	1638	5982	8.8	738	1309	2.6	743941	8173841	33.3
19	2492	5832	4.5	305	1935	17.8	410735	8408931	64.9
20	3139	2547	-0.6	694	680	-0.1	1546816	1160386	-0.8
21	5249	3304	-1.2	1450	703	-1.7	7151553	1436439	-2.7
22	6162	3448	-1.5	1760	880	-1.7	8278769	1677171	-2.7
23	5643	2396	-1.9	1921	434	-2.6	8157500	1101159	-2.9
24	4570	1339	-2.4	1216	448	-2.1	2880185	386001	-2.9
25	3278	300	-3.0	882	109	-2.9	1669338	190737	-3.0
26	2578	2426	-0.2	565	1502	5.5	847896	2768175	7.5
27	2536	5064	3.3	1484	1411	-0.2	3058628	4036041	1.1
28	3128	2462	-0.7	718	2534	8.4	1235404	4452652	8.7

*PB- Point bars, T-Max- Total Maximum, T-Min- Total Minimum, T-Ave- Total Average,

YR- Year, RC- Rate of change, Negative (-) values refer to erosion, Nil- not present in that year.

Table 1 continued: Variation in geometric dimensions (length, width and area) of point bars (PB) within the Niger Delta between year 1985 and year 2015.

PB S/N	LENGTH (M)			WIDTH (M)			AREA (M^2)		
	YR 1985	YR 2015	% RC	YR 1985	YR 2015	% RC	YR 1985	YR 2015	% RC
29	3557	5823	2.1	3118	885	-2.4	8765554	4277302	-1.7
30	1440	3162	4.0	350	1875	14.5	340083	4173703	37.6
31	1926	3533	2.8	1936	1334	-1.0	3165994	5985016	3.0
32	3404	2570	-0.8	1576	1828	0.5	3552385	4330978	0.7
33	3485	3454	0.0	1376	2473	2.7	5711433	6058858	0.2
34	2286	1954	-0.5	1801	2363	1.0	4077233	4040931	0.0
35	1976	1135	-1.4	4031	2219	-1.5	4855496	3207949	-1.1
36	2210	2136	-0.1	1808	433	-2.5	3883059	826667	-2.6
37	476	561	0.6	116	101	-0.4	33172	53286	2.0
38	579	nil		134	nil		56964	nil	
T-Min	476	300	-3.0	116	101	-3.0	33172	53286	-3.2
T-Max	9305	8604	8.8	4896	6490	17.8	22499273	21819150	64.9
T-Ave	3988	3837	0.6	1651	1938	2.5	4475689	6103804	8.6

PB- Point bars, T-Max- Total Maximum, T-Min- Total Minimum, T-Ave- Total Average,

YR- Year, RC- Rate of change, Negative (-) values refer to erosion, Nil- not present in that year.

Table 2: Summary table for plots of point bar geometric dimensions dependence of a parameter against another.

Plots for point bar geometric dimensions			
Year	**PLOT**	**R^2**	**Comment**
1985	Point bar Length against Point bar Width	0.3	No significant relationship
2015	Point bar Length against Point bar Width	0.4	No significant relationship
1985	Point bar Width against Point bar Area	0.6	Significant relationship
2015	Point bar Width against Point bar Area	0.8	Significant relationship
1985	Point bar Length against Point bar Area	0.6	Significant relationship
2015	Point bar Length against Point bar Area	0.7	Significant relationship

5. Conclusions

A total of 75point bars were analyzed, 38 in 1985 and 37 in 2015. Averagely the point bars identified in 2015 are greater in geometric dimensions than those identified in 1985. The average percentage rate of change in the length and width of the point bars were identified to be 0.6% and 2.6% respectively and average of 8.6% rate of positive change affected the area of the point bars over the period of study (30 years). The coefficient of determination result suggests that there are no relationships between the width and length of point bar deposits within the River Niger channel. It is therefore unreliable to utilize width to predict the length of a point bar deposit or vice versa unless more data is incorporated. Remote sensed studies provide valuable information on the geometry of point bar deposits, in modern fluvial systems, which can serve as analogs, for the efficient characterization and development of hydrocarbon reservoirs in ancient fluvial channel bar deposits

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